# Radar Detection of Marine Mammals

Charles P. Forsyth
Areté Associates
1550 Crystal Drive, Suite 703
Arlington, VA 22202
phone: (703) 413-0290 fax: (703) 413-0295 email: cforsyth@arete.com

Award Number: N00014-07-C-0885
http://arete.com

## LONG-TERM GOALS

The long term goal is to develop a radar solution for the detection of marine mammals using ship-borne radar and demonstrate its performance. In particular, a solution using commercial surface search radars is desired as it provides a readily accessible technique for commercial shipping concerned about ship strike of marine mammals and/or detection for compliance with operating permits.

## OBJECTIVES

There are two technical objectives for this work. The first is to develop a near-real-time signal processor/radar combination that is suitable for the detection of marine mammals. The second objective is to assess the performance of such a combination in specific ocean conditions / species combinations in order to establish the utility of such a system.

## APPROACH

The general approach is to iterate between experimental results and processing improvements. As such, the current work represents one cycle of development. There are three elements to the approach as follows:

The first task is to collect a data set from a fixed location. The dataset should have significant diversity in (a) look directions, (b) range from the radar and (c) sea conditions. The dataset should have sufficient animals to make a statement about both probability of detection (PD) as well as false alarm rate (FAR).

The second task is to make an assessment of the performance of the radar plus signal processing algorithm for the detection of marine mammals

The third is to convert the algorithm into a low-latency processor suitable for a ship borne application where a mitigation action may need to be undertaken in response to a detection.

The resulting processor will then be tested in a ship borne test. This will be followed by a number of iterations to improve both the timeliness of the processor as well as a reduction in the FAR.

# Report Documentation Page

*Form Approved*
*OMB No. 0704-0188*



| | | |
|---|---|---|
| 1. REPORT DATE<br>**2010** | 2. REPORT TYPE | 3. DATES COVERED<br>**00-00-2010 to 00-00-2010** |
| 4. TITLE AND SUBTITLE<br>**Radar Detection of Marine Mammals** | | 5a. CONTRACT NUMBER |
| | | 5b. GRANT NUMBER |
| | | 5c. PROGRAM ELEMENT NUMBER |
| 6. AUTHOR(S) | | 5d. PROJECT NUMBER |
| | | 5e. TASK NUMBER |
| | | 5f. WORK UNIT NUMBER |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)<br>**Aret?ssociates,1550 Crystal Drive, Suite 703,Arlington,VA,22202** | | 8. PERFORMING ORGANIZATION REPORT NUMBER |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) | | 10. SPONSOR/MONITOR'S ACRONYM(S) |
| | | 11. SPONSOR/MONITOR'S REPORT NUMBER(S) |
| 12. DISTRIBUTION/AVAILABILITY STATEMENT<br>**Approved for public release; distribution unlimited** | | |
| 13. SUPPLEMENTARY NOTES | | |
| 14. ABSTRACT | | |
| 15. SUBJECT TERMS | | |

| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT | 18. NUMBER OF PAGES | 19a. NAME OF RESPONSIBLE PERSON |
|---|---|---|---|---|---|
| a. REPORT<br>**unclassified** | b. ABSTRACT<br>**unclassified** | c. THIS PAGE<br>**unclassified** | **Same as Report (SAR)** | **5** | |

## WORK COMPLETED

During this period, we conducted an at-sea data collection. We accompanied the NOAA Southwest Fisheries "Ecosystem Survey of Delphinus Species" (ESDS) cruise aboard the R/V MacArthur II . For this test, we tapped into the existing ship's X-band Furuno radar. (See **Figure 1**).

***Figure 1. NOAA R/V MacArthur II. The red circle highlights the 8 ft X-band Furuno radar used in the experiment.***

The data from this cruise was analyzed and several problems were identified. First, most of the data was collected in the crude-resolution M2 mode. Second, the tracker that was developed to provide tracks for the marine mammals was unable to effectively distinguish between true marine mammal tracks and noise-related tracks. This led us to a two-fold approach involving an alternate tracker for the MacArthur II data and a re-examination of a previous data case from the Mediterranean. These results are described below.

## RESULTS

Participation in the NOAA "Ecosystem Survey of Delphinus Species" cruise resulted in a large radar database of marine mammals in moderate to high sea states. Integration of the data recorder into the MacArthur II's Furuno radar was successful and over 500 hours of radar data were collected. However, for operational reasons, the radar was typically operated in M2 mode. This mode achieves a greater detection range for ships by degrading the spatial resolution significantly and was used as the primary navigation radar for the ship. While some data was collected in the higher resolution S1 mode, this was typically performed at night when there were no visual observations.

The NOAA cruise included, for its primary purpose, a team conducting visual observations for various census purposes. We took advantage of this to make a direct statistical comparison between the visual observations of large marine mammals and radar observations. A total of 42 visual observations were used with corresponding M2 mode radar data. Initially, a associative tracker using the Munkres algorithm was used. This was then expanded to include a track-before-detect algorithm, the Baysean Field Tracker (BFT).

One difficulty that was encountered was the metrics to be used for the comparison. Due to the large location errors in the visual observations an attempt was made to identify a region where the whale could actually be found. For each visual observation an elliptical search region was defined based on the range of the observation. In addition, we were typically limited to one observation per mammal group. This visual observation may be a direct observation of the animal's back or a spout. However, the radar is not sensitive to spouts and so the timing of the visual observation may not exactly match the corresponding radar detection, thus requiring a radar detection at a specific time was inappropriate. This was fixed in concept by requiring a radar track to correspond to a visual observation within a certain amount of time either before or after the visual observation. This in turn required that the search region had to grow at a rate consistent with whale speeds which were taken to be a maximum of 5 knots. While this provided for successful radar-visual correspondence, it had disastrous consequences for the corresponding false track analysis.

In order to assess the false tracks, a set of false visual contacts were generated by mimicking the range and bearing of the actual visual observations in locations that were believed to be whale-free. Thus, a dataset was created with a large number of potential false tracks that had a close similarity to the actual observations. This dataset was then processed in an identical manner to the actual observations.

Figure 2 shows a plot of the percentage of visual observations with a corresponding radar track within its search region as a function of the time between the visual observation and the radar track. The red line shows the results with the actual observations versus the black curve for the false observations along with a set of 1-sigma error bars. Not surprisingly as the time window grows (and as a result the search region) the fraction of animals detected also grows. However, the same can be said for the random sample and in fact the number of detections in the random sample matches very closely those of the actual observations. What this plot shows is that while we may be detecting whales they can not be distinguished due to the large number of false alarms. Thus, no conclusion can be reached about whether or not whales were detected.

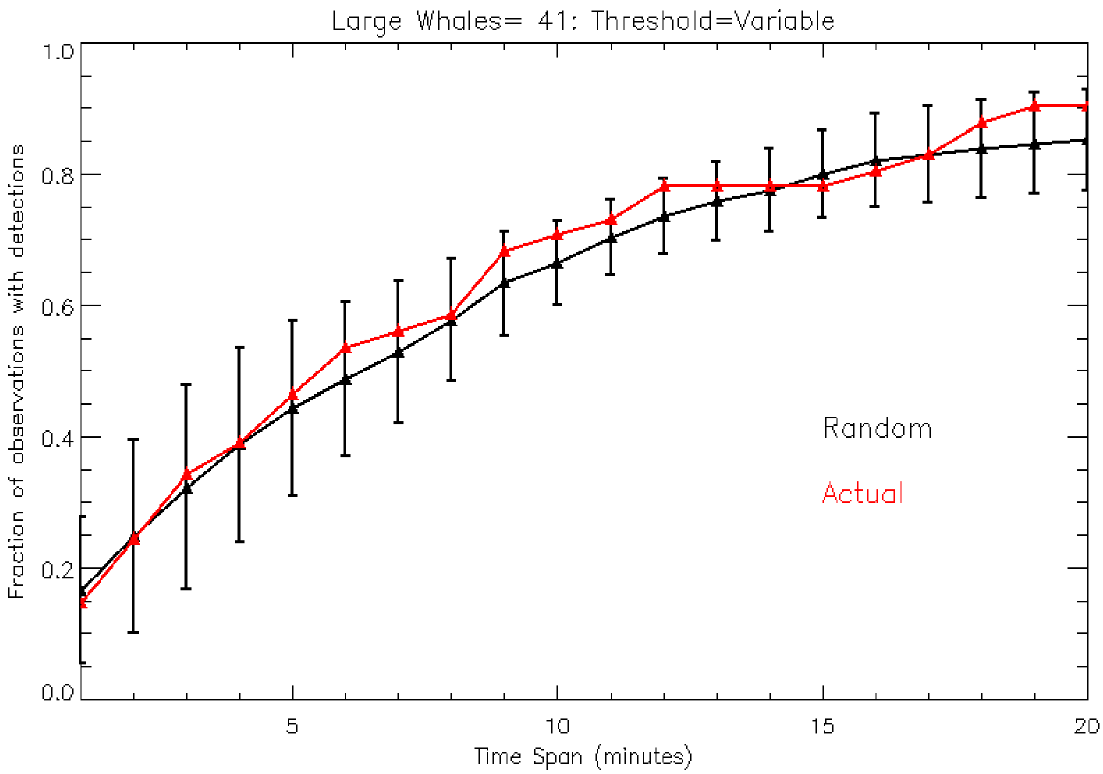


***Figure 2. Fraction of visual observations with corresponding radar detections for both real and random data sets.***

The failure of the associative tracker to make useful tracks in the ESDS data set appears to be driven by three elements. First, the weak signature of the whales relative to the clutter results in a low detection threshold in order to make detections at the scan level. This in turn drives the false detection rate higher which then opens the gates for a lot of false tracks. Second, the tracks are typically short duration (three scans) because of a combination of the intermittent exposure of the whales coupled with the rotation rate of the commercial-grade Furuno radar. Third, the large resolution size of the M2 mode lowers the overall sensitivity to small, slow moving objects (i.e. whales).

In order to address the third concern (M2 mode), we have tested using a track-before-detect tracker termed the Baysean Field Tracker. This tracker seeks to increase the performance against noise by delaying the detect threshold until multiple scans are processed. This tracker has been used successfully in other low signal problems. However, the technique was not able to overcome the noise issues found in the M2 data. As a result, we have abandoned use of M2 mode for marine mammal detection.

We have also tested the associative tracker against a previously collected data set from the CEDAR data collection in the Mediterranean. This dataset tended to be skewed to lower sea states and was conducted entirely in S1 mode from similar Furuno radar. In addition, the CEDAR cruise included dedicated visual observers who were instructed to give as many resights as possible for each mammal group.  Despite these advantages, the associative tracker produced similar results as the ESDS data set. The same first two causes were identified as likely causes.

We are currently working to apply the BFT processor to the CEDAR data. This tracker should help mitigate both identified causes and represents our last option for use of the commercial radar for marine mammal detection from ships for collision avoidance.

## IMPACT/APPLICATIONS

The project can provide a significant new capability for operations in and around marine mammals. If the commercial radar approach is successful, a relatively low-cost solution will be available to detect and track marine mammals. This capability can be used to extend operations into low visibility conditions (e.g. night and fog) for both ship strike avoidance applications as well as area clearance operations around active sources. Since the capability can be configured to use existing radars, there is relatively low impact on commercial ships use of the technology. Similar approaches can be developed for military-grade radars if desired.

## RELATED PROJECTS

None.